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ANTHROPOLOGY.—*The Ainu double foreshaft toggle harpoon and western North America.*[1] GORDON W. HEWES, University of California. (Communicated by HENRY B. COLLINS, JR.)

O. T. Mason (1900, p. 233) noted the similarity of Ainu double foreshaft harpoons to those of northwestern North America. Distributional data are now far more complete for the latter area, and it seems worth while to reexamine an apparently significant Asiatic-American parallel. First, as to the Asiatic occurrence, it must be admitted that the writer has not been able to find any descriptions of the Ainu implement that include material unavailable to Mason in 1900. Hitchcock (1890, pp. 470–471, 494) described and illustrated an Ainu harpoon in the U. S. National Museum collection, but this differs in details from Batchelor's reference (1892, pp. 154–155); subsequent references to Ainu double foreshaft harpoons in the literature are unfortunately content to refer to these sources (e.g., Montandon, 1937). Batchelor's further Ainu writings reproduce the 1892 drawing. The following quotation and Fig. 1, *a*, constitute Batchelor's original reference:

> Trout and pike are caught with a spear called *chinininiap*, or *apniniap*. The handle of this spear is about eight or nine feet long, and when fitted up ready for use it is fully ten feet in length. As will be seen from the figure, this spear has two heads to it, which are fastened to the pole by means of string. These heads are barbed, and consist of two parts—an iron point and a bone foundation. As soon as a fish is struck with this spear, the barbed heads come off the points of the pole, but the fish is secured by means of the strings which are attached to the spear-heads and back part of the shaft or pole.

Unmentioned but noteworthy are the string connecting the foreshafts midway between the toggles and the main shaft and the fact that one of the foreshafts is shorter than the other. In the drawing the strings from the toggles are clearly shown attached to the shaft; while other Ainu specimens may have longer lines, held in the user's hand, or lying coiled in the canoe; such is not the case here. Hitchcock deals with a larger device, used for seals, whales, turtles, and large fish; it is shown in Fig. 1, *b*, *c*. Though the arrangement and proportions of the two foreshafts, toggles, and the reinforcing string between the foreshafts are the same, the toggles are connected to a tough strip of hide, to the middle of which is attached a long, braided, bark, rope line, shown looped around the main shaft and passing on into a loose coil. This line when the harpoon is in use is stated to pass over the ornamented crotch at the distal end of the shaft, shown in Fig. 1, *c*. The length of the National Museum's specimen's shaft is 15 feet.

Thus there seem to be two types of double foreshaft toggle harpoons used by the Ainu, the one for smaller fish—trout and pike—in which the toggles are tied directly to the shaft, and a larger one, with a long hand line, for sea mammals, sharks, and swordfish. It is probable that for the smaller fish, the harpoon was thrust, not thrown clear of the user's hands, and the quarry retrieved simply by pulling in the shaft, to which the embedded toggle is attached. With sea mammals and larger fish, the whole harpoon is thrown clear, the user

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retaining the line in his hands; the floating wooden shaft impedes the efforts of the animal to escape. Japanese paintings illustrate this technique (Greey, 1884, p. 52). Findeisen (1929, p. 28 ff.) mentions the two types of harpoons and contrasts them in respect to the toggle-lines. The Ainu are said by Hitchcock to poison their toggles occasionally with aconite (presumably this would apply only to the sea-mammal harpoon, as there would be no need to poison harpoon points for fish). On the Asiatic-American distribution of this poison, see Heizer's report (1938a). The Ainu do most of their salmon (*Oncorhynchus*) fishing not with harpoons, but with the *marek*, an iron hook resembling a gaff, but with a trigger action that pins the fish to the shaft; *mareks* have been described by many writers on the Ainu, including Hitchcock, Batchelor, Montandon. The Ainu also fish with hook and line, nets, traps, etc.

In northeast Asia, only the Ainu and Amur peoples fish with harpoons (Findeisen, 1929, p. 28), and while Chukchi, Koryak, and Kamchadal used harpoons for sea-mammal hunting, these were all of the single-toggle type, or the socketed foreshaft and multiple barbed head type. The double foreshaft toggle harpoon is restricted to the Ainu; review of the available Gold, Gilyak, and Udekhe material yields references only to single toggle and barbed types. Harpoon fishery has been described for the Manchu and Gold (Lattimore, 1933, pp. 33–34), as well as for the coastal Udekhe (Arsenjew,

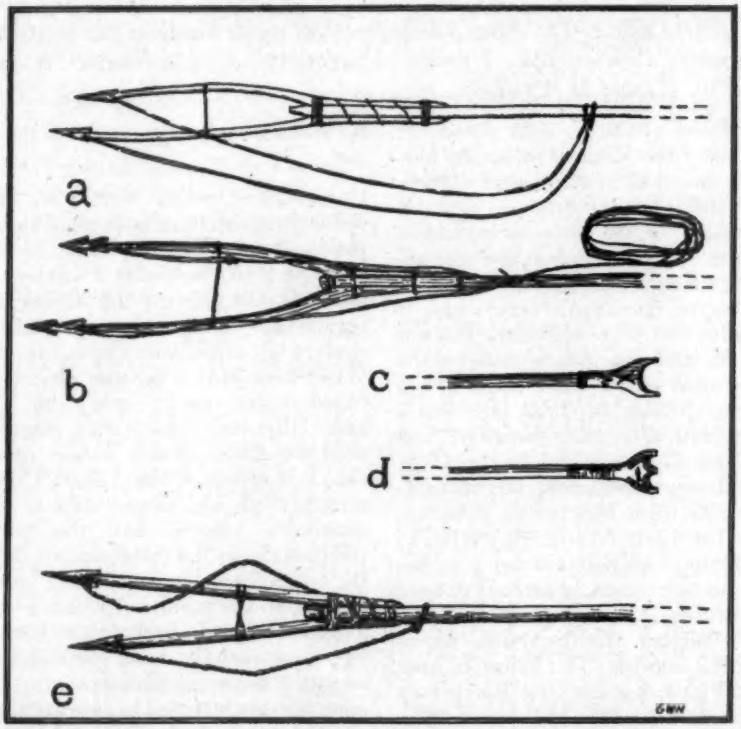

FIG. 1.—*a*, Ainu harpoon (after Batchelor, 1892, p. 154); *b*, Ainu harpoon (after Hitchcock, 1890, p. 470); *c*, Ainu harpoon, base of shaft showing ornamented device (Hitchcock, 1890, p. 470); *d*, Kwakiutl harpoon base device (after Goddard, 1924, p. 61); *e*, Wailaki (California) harpoon, from a photograph by the writer, 1940.

1924, vol. 2, pp. 137, 276). The Sakhalin Ainu use a sealing spear with a single offset foreshaft, for use under the edges of broken ice (Greey, 1884, pp. 274–275).

The situation in western North America is decidedly different (see Fig. 2, map). The double foreshaft toggle harpoon occurs in 60 native tribes at least, from Vancouver Island southward along the coast almost to San Francisco Bay, and inland from the toggle head were used by many groups as alternatives to the double foreshaft type, and by some groups exclusively, though in the northwestern California area by preference rather than through ignorance of the double foreshaft device. In the eastern Plateau and the northeastern Basin, only single toggle harpoons were employed. Finally, many types of thrusting and hurling implements, often confused in the

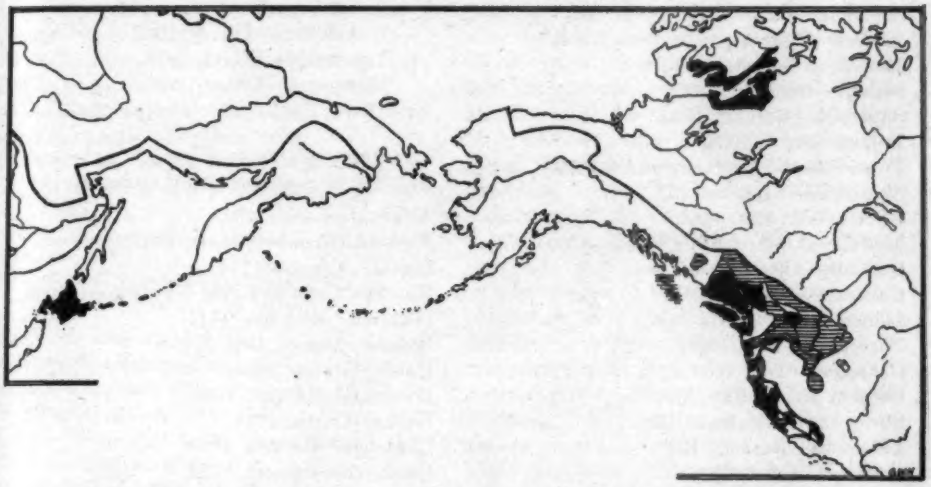

FIG. 2.—The North Pacific area, showing the distribution of double foreshaft toggle harpoons (in black), single toggle harpoons (in Northwest coast, Plateau, and California-Basin areas only; horizontal hatching), and the boundaries of Pacific salmon, i.e., *Oncorhynchus*, fishery (heavy black line).

Chilkotin to the southernmost Yokuts of the San Joaquin Valley, as well as on the Arctic coast among the Copper Eskimo. Over most of the area within the Pacific drainage, the implement is used for taking the large salmon (*Oncorhynchus*), but on the southern Northwest coast the device was employed frequently for seal and porpoise.

One must carefully distinguish the double foreshaft toggle harpoon in western North America from other harpoon and harpoon-like devices used in the pursuit of aquatic animals. From Alaska south as far as the Mattole River in California, the larger sea mammals were taken with a single-pointed barbed harpoon. Harpoons with a single literature with harpoons, were used: Barbed fish-spears, gaff hooks, bidents, and tridents. The trident fish-spear, or leister, was common in western North America, though the literature indicates that it was lacking, at least in recent times, south of the Columbia River, except among the Umatilla (Ray, MS.). Transitions between trident and harpoon occur in the Plateau, in which the three prongs were detachable as a unit, the main shaft fitting into a socket in the butt of the middle prong (Ray, MS.; and Ray, 1933).

The following lists of tribes and references constitute the basis of the map, Fig. 2 (the listings in parentheses are uncertain):

TRIBES USING DOUBLE FORESHAFT TOGGLE HARPOONS IN NORTHWESTERN AMERICA

Copper Eskimo—Rasmussen, 1932.
Kwakiutl—Boas, 1909; Barnett, 1939.
Nutka—Curtis, 1916.
Gulf of Georgia Salish—Barnett, 1940.
Sanetch—Barnett, 1939.
Cowichan—Barnett, 1939.
Nanaimo—Barnett, 1939.
Pentlatch—Barnett, 1939.
Comox—Barnett, 1939.
Slaiamun—Barnett, 1939.
Klahuse—Barnett, 1939.
Homalco—Barnett, 1939.
Sechelt—Barnett, 1939.
Squamish—Barnett, 1939.
Lummi—Stern, 1934.
Puget Sound—Haeberlin and Gunther, 1930.
Skokomish—Gunther, MS.
Klallam—Gunther, MS.
Makah—Gunther, MS.; Mason, 1900.
Quinault—Olson, 1936.
Chilkotin—Morice, 1910.
Lillooet—Ray, MS.
Thompson—Teit, 1900.
Okanagan—Teit, 1930.
Coeur d'Alene—Ray, MS.
Lower Chinook—Ray, 1938.
Tillamook—Barnett, 1937.
(Alsea—Drucker, 1939).
Siuslaw—Barnett, 1937.
Galice Creek Athabaskans—Barnett, 1937.
Chetco—Barnett, 1937.
Tolowa—Driver, 1939.
Yurok—Driver, 1939.
Karok—Driver, 1939.
Hupa—Driver, 1939; Goddard, 1903.
Wiyot—Driver, 1939.
Chilula—Driver, 1939.
Mattole—Driver, 1939.
Sinkyone—Driver, 1939.
Kato—Driver, 1939; Essene, MS.
Coast Yuki—Driver, 1939; Gifford, 1939.
Lassik—Essene, MS.
Yuki—Essene, MS.
Pomo-Kabedile—Gifford and Kroeber, 1937.
Buldam-Willits—Gifford and Kroeber, 1937.
Kacha-Bida—Gifford and Kroeber, 1937.
Shanel (North)—Gifford and Kroeber, 1937.
Yokaia—Gifford and Kroeber, 1937.
Northeastern—Gifford and Kroeber, 1937
Klamath (and Modoc)—Spier, 1930.
(Achomawi—Kniffen, 1928).
Yana—Gifford and Klimek, 1936.
Wintu—DuBois, 1935.
Hill Wintun—Gifford and Kroeber, 1937.
Miwok—Barrett and Gifford, 1933.
Mono-Tuhukwadj—Driver, 1937.
Wopunuch—Driver, 1937.
Entimbich—Driver, 1937.
Waksachi—Driver, 1937
Yokuts-Choinimni—Driver, 1937.
Wukchamni—Driver, 1937.
Yaudanchi—Driver, 1937.
Yauelmani—Driver, 1937.
Kern River Bankalachi—Driver, 1937.

TRIBES USING SINGLE TOGGLE HARPOONS IN NORTHWESTERN AMERICA

Aleut—Jochelson, 1925.
Western Eskimo—Nelson, 1897.
Ingalik—Osgood, 1940.
Kutchin, Crow and Peel R.—Osgood, 1936.
(Tahltan—Emmons, 1911).
Babine—Morice, 1910.
Haida—Mason, 1900.
Kwakiutl—Barnett, 1939.
Nutka—Curtis, 1916.
Cowichan—Barnett, 1939.
Pentlatch—Barnett, 1939.
Comox—Barnett, 1939.
Squamish—Barnett, 1939.
Skokomish—Gunther, MS.
Makah—Mason, 1900; Densmore, 1939.
Shuswap—Teit, 1909.
Okanagan—Teit, 1930.
Kutenai—Teit, 1909; Turney—High, 1941.
(Flathead—Teit, 1930).
Sanpoil-Nespelem—Ray, 1933.
Spokan—Curtis, 1911.
Coeur d'Alene—Teit, 1930.
Nez Percé—Spinden, 1908.
Lower Chinook—Ray, 1938.
Santiam Kalapuya—Jacobs, MS.
Alsea—Drucker, 1939.
Tututni—Barnett, 1937.
Takelma—Sapir, 1907.
Chetco—Barnett, 1937.
Tolowa—Drucker, 1937; Barnett, 1937.
Yurok—Driver, 1939.
Karok—Driver, 1939.
Wiyot—Driver, 1939.

Chilula—Driver, 1939.
Chimariko—Driver, 1939.
Van Duzen (Nongatl)—Driver, 1939.
Sinkyone—Driver, 1939; Nomland, 1939.
Lassik—Essene, MS.
Coast Yuki—Driver, 1939.
Yuki—Essene, MS.
Pomo-Kalekau—Gifford and Kroeber, 1937.
Shanel (South)—Gifford and Kroeber, 1937.
Meteni (Fort Ross)—Gifford and Kroeber, 1937.
Wappo—Driver, 1936.
Pomo-Makahmo—Gifford and Kroeber, 1937.
Hill Patwin—Gifford and Kroeber, 1937.
Nisenan—Beals, 1933.
Shoshoni-Lemhi—Steward, 1941.
Snake River—Steward, 1941.
North Fork of Owyhee River—Steward, 1941.
Battle Mountain—Steward, 1941.

TRIBES USING BARBED HARPOONS IN NORTHWESTERN AMERICA

Aleut—Jochelson, 1933.
Western Eskimo—Nelson, 1897.
Ingalik—Osgood, 1940.
Tanaina—Osgood, 1937.
Eyak—Birket-Smith and DeLaguna, 1938.
Tlinkit—Krause, 1885.
Haida—Mason, 1900; Curtis, 1916.
Kwakiutl—Boas, 1909.
Nutka—Mason, 1900.
Quinault—Olson, 1936.
(Thompson—Teit, 1900).
Tillamook—Barnett, 1937.
Siuslaw—Barnett, 1937.
Kus—Barnett, 1937.
Sixes River—Barnett, 1937.
Chetco—Barnett, 1937.
Tolowa—Barnett, 1937; Drucker, 1937.
Yurok—Driver, 1939.
Wiyot—Driver, 1939.
Mattole—Driver, 1939.
(Chumash and Nicoleño—Nelson, 1936).

Illustrated specimens of double foreshaft toggle harpoons from northwestern America show the expectable local variations in details and workmanship, so that it is fairly easy to pick out examples that closely resemble the Ainu types (see Fig. 1, *e*). The large Nutka and Kwakiutl porpoise and seal harpoons are similar in most details, including dimensions, to the Ainu specimen illustrated by Hitchcock (1890, fig. 85, p. 470; cf. Boas, 1909, p. 488 ff., and Curtis, 1916, p. 74). Even the construction of the toggles is similar; the foreshafts are of unequal length (more so in the Nutka and Kwakiutl examples than in the Ainu), and, perhaps most significant of all, the base of the main shaft has an expanded device, slightly indented at two points along the butt to form a blunt trident. This object, like the Ainu crotched shaft base, is decorated—in a Kwakiutl specimen, with a fish design and ornamental border. The Pentlatch in the Gulf of Georgia perhaps approach the Ainu more closely, for they use a "cupped" base as an alternative to the blunt "trident" (Barnett, 1939, p. 229; a diagram of the trident base is shown on p. 279, n. 39). Boas (1909, p. 495) suggested that the notched handle-end device is closely related to the spear-thrower. If the suggestion were valid, we would expect to find similar devices on the bases of harpoons and spears among peoples who possess the spear-thrower, since it is lacking on the southern Northwest coast and is also unknown to the Ainu. Tlinkit, Eskimo, and Aleut harpoons and spears have nothing resembling the crotched or trident expanded base. If similarities must be found, the expanded crotch bases of harpoon *arrows*, as used on the Bering Sea, are more convincing, although the writer is inclined to question the significance of this parallel (Mason, 1900, pl. 16, fig. 4, and pl. 17, fig. 2; cf. Kwakiutl arrows, in Goddard, 1924, p. 76, *e*). According to Hitchcock, the expanded base on the hurling harpoon is for the line to pass over; if this is true, Japanese drawings of the Ainu about to hurl harpoons are at fault, because they show the line going no farther than the thrower's hands. Mason's drawing (1900, fig. 19, p. 226) of a Quinault using a harpoon of this type has the line coiled in the thrower's right hand, while Curtis (1916, pl. 74) shows the Nutka harpoon line coiled on the thrower's left wrist. Whatever the etiology of the device may be, the striking similarity of the Ainu and southern Northwest coast

occurrences remains significant, in the absence of anything similar in between.

In another detail, closer correspondences are to be found in the harpoons from certain Californian groups. The reinforcing string connecting the foreshafts of unequal length is present on both types of Ainu double foreshaft toggle harpoons. Although this is not noted from the southern Northwest coast (it may have been present but gone unnoticed by the authors of our sources), it is a common trait of Wailaki, Mattole, Yuki, and Lassik harpoons in northwest California. The author's informants in the latter area explained the string connecting the foreshafts as a necessary reinforcement, "to keep the prongs from spreading" in the words of a Mattole. A Wailaki added that the string might be adjusted in order to alter the distance between toggles.[2] The inequality of the foreshafts was explained variously by informants in this area. A Mattole said that the longer prong was held above, and that the shorter foreshaft and its toggle would strike the fish if the upper one missed; similar reasons were voiced by a Yuki and a Sinkyone, the latter remarking that young men used a single foreshaft type, since they had good aim. A Wailaki thought the inequality was to prevent simultaneous breakage of the points of both toggles if the harpooner struck a submerged rock by mistake.

A simple experiment in water with models will convince anyone that the presence of two divergent foreshafts increases the likelihood of a successful strike, if the foreshafts are held one above the other. A quick thrust carefully aimed at the refracted image of a submerged object, in any but a vertical direction, will carry the point of a single shaft well above the actual target; to the error of aim due to refraction is added the tendency for the buoyant shaft to swerve upward. While practice with a single foreshaft harpoon might enable one to compensate for the refraction by aiming well below the apparent position of the target, it seems that use of two foreshafts is a simpler and surer way of overcoming the difficulty.

[2] Field notes of the author, 1940.

How is the Ainu harpoon to be interpreted in the light of these facts? Direct trans-Pacific diffusion from Yezo to the southern Northwest coast and California, or the reverse, seems quite improbable. On a pure age-area basis, diffusion would seem to have been from America to Asia, since the trait is far more widespread in the former continent. If careful search of Japanese sources showed no evidence for the Ainu occurrence prior to the early nineteenth century, one might venture to ascribe its introduction to the ubiquitous Aleut sea-otter hunters in Russian service, who may conceivably have picked up knowledge of the device while hunting on the American coast anywhere from Vancouver Island to California.[3] Conclusive settlement of this point requires Japanese documentation which the writer at present cannot undertake, but the facts surrounding the Ainu trait under discussion, together with archeological hints from Japan itself, to say nothing of the improbability of Aleuts as neutral go-betweens in the transfer, leads the writer to seek for a more plausible explanation based on present evidence.[4]

Independent invention of double foreshafted toggle harpoons in Yezo and northwestern America, while not transcending ethnological possibilites, also seems doubtful. A convergence theory might well cite the numerous transitional types between single toggle harpoons and double foreshaft toggle harpoons, such as double foreshaft types, wherein one point is fixed, the other detachable, as reported from some Mono and Yokuts groups by Driver (1937, n. 157), or double foreshaft *fish-spears*, along with tridents and bidents detachable as a

[3] Mason (1900, p. 298) notes the introduction of Aleutian harpoon arrows and the sinew backed bow to the Kuriles (presumably to the Kurilian Ainu) by nineteenth-century Aleut otter hunters; aboriginally the Yezo Ainu used a simple yew bow. (The double foreshaft toggle harpoon is not mentioned by Jochelson, 1933, for the Aleut.)

[4] One is reminded, however, of the caution with which one must approach any question of autochthony of artifact types by Heizer's critical inquiry into the status of the Santa Barbara (Chumash) spear-thrower (1938b, pp. 137–141), wherein a device long uncritically regarded as indigenous to California is tentatively attributed to Mexican Indian contacts in post-Spanish times.

whole from the shaft, found in the Plateau (Ray, 1933; Ray, MS). The Eyak used a bident fish-spear with nondetachable barbs (Birket-Smith and DeLaguna, 1938). Further, the actual advantages of divergent foreshafts as demonstrated by the experiment described above, might be adduced as evidence to prove the likelihood of independent invention. There is no gainsaying the fact that the harpoon toggle principle has been applied to a variety of related thrusting and hurling implements in northwestern America. Nevertheless, the continuous or near-continuous distribution of double foreshaft toggle harpoons within the coastal area of the *Oncorhynchus* fishery in northwestern America, and the peripheral distribution of other forms such as tridents detachable as a unit, single-toggle harpoons, etc., strongly suggests a single origin for the double foreshaft type, without of course denying the rather obvious derivation of the invention from a simple, single-toggle harpoon ancestor. The Copper Eskimo occurrence, illustrated by Rasmussen, may fit into the general interpretation later on in this paper. Typologically, both the Ainu examples belong in the western American series. There is nothing in the harpoon situation of the Amur and northeastern Asiatic region to correspond to the variety of transitional forms encountered in northwestern America. Outside the Yezo region, fishing and sea-mammal harpoons are uniformly either single toggle or single barbed-headed types, the latter provided with the elaborate bone or ivory slotted foreshaft typical of the Bering Sea. Improbability of the convergence of Ainu and American forms is increased by the occurrence of such features as the crotched and ornamented base, unequal length of foreshafts, and the presence of reinforcing string between them. A survey of harpoon types in various parts of the world indicates that while there is undoubtedly an ultimate limitation of the possibilities of formal variation in these devices, the range is very great (Gruvel, 1928, pp. 81–90).

An interpretation based on assumption of an earlier continuity in the distribution of the double foreshaft toggle harpoon from Yezo to the southern Northwest coast seems to be called for. As both barbed and toggle single-pointed harpoons have wide distributions in both northeastern Asia and America, there can be no serious suggestion that the continuity of double-foreshaft toggle harpoons assumed in this interpretation represents the prior type. *Barbed* harpoon heads occur frequently in archeological sites in the northern Eurasiatic region, beginning as far back as the European Magdalenian and aspects of similar antiquity from Siberia such as Vercholensk Mountain and Mal'ta (Childe, 1936; see also, s. v. Sibirien, Ebert's *Reallexikon der Vorgeschichte*). Moreover, in the Mesolithic remains from Ulan Khada, Lake Baikal, which are regarded by some as approaching the postulated proto-American culture of the first migrants, fish-spears and harpoons of barbed type occur (Clark, 1940).[5] In America, the earliest and still the most widespread harpoon type is barbed; Fuegian harpoons are barbed and provided with wedge-shaped tangs (Mason, 1900, pl. 2, p. 213). Single toggle harpoons likewise have a more extensive distribution in time and space than the specialized double foreshafted toggle variety. Birket-Smith (1929, pt. 2) has a discussion of these distributions.

Except under unusual conditions for preservation, evidence for double-foreshafted toggle harpoons does not survive archeologically. Bone toggle-heads by themselves give no indication of their use in pairs, while wooden foreshafts and lashing seldom last more than a few years in the ground. Our interpretation is thus practically restricted to inferences from ethnography and the negative evidence of archeology. As stated above, barbed harpoons occur within the northwestern American distribution of double foreshaft toggle harpoons, along the coast, where they are used for sea mammals but not for fishing. Inland, there is archeological evidence for the abandonment of barbed fishing harpoons at no remote time, in regions where toggle harpoons were used subsequently, or harpoons were

[5] They occur also in Predynastic Egypt; cf. Bates, 1917.

given up altogether. In the ethnography of the Lower Sacramento Valley, there is no clear evidence of the use of barbed fishing harpoons; element lists and ethnographies cite only the toggle type (cf. Beals, 1933, fig. 1, p. 431—Nisenan). Yet, in the area occupied historically by Patwin, Nisenan, and northern Yokuts, archeology yields numerous unilaterally and bilaterally barbed harpoon points. These are not associated with the *Early* culture horizon, but occur in the *Late Period* (Lillard, Heizer, and Fenenga, 1939, pl. 29; Heizer and Fenenga, 1939, fig. 1, p. 384). Schenck and Dawson (1929, p. 369, pl. 80) attribute them to Aleut sea-otter hunters operating at the beginning of the nineteenth century, but this supposition is not entertained by later investigators.

A Kacha-Bida (Northern) Pomo informant stated that double foreshaft toggle harpoons were recent introductions, and that anciently only single-pointed fish-spears were used (Gifford and Kroeber, 1937, p. 173, n. 210). In the same general area the writer noted a well-preserved multibarbed fish-spear found near Clear Lake under conditions suggesting some antiquity, now in the Lake County Museum, Lakeport. Questioning of native informants at Clear Lake and elsewhere in northern California yielded only denials that any such spear type was known. This evidence, unsatisfactory as it is, indicates that multibarbed fish-spears and harpoons were formerly in use in inland central California, though they went out of use before the period covered by memories of surviving informants. Archeological evidence of a similar abandonment of barbed harpoons has come from central Utah (Gillin, 1940, pp. 170–171) and from the Red River Valley, N. Dak. (Jenks, 1932, pp. 456–459).

In the Eskimo area and in southern Alaska, both toggle-heads and barbed harpoon points occur in the most ancient horizons. While changes in the construction of toggle-heads are significant criteria for Eskimo culture periods, there is no level at which toggles suggestive of the cruder type used on double foreshaft toggle harpoons in the northern Plateau and California occur (Collins, 1940, p. 550 ff., pl. 16). Even at Ipiutak, Point Hope, presumably antedating any other Eskimoid culture in the Bering Sea region, toggle and barbed harpoon heads occur, though not with great frequency (Rainey, 1941, p. 170). No evidence bearing on our problem has yet come to light from the recent work in central Alaska on accidentally discovered artifacts from muck-deposits, in apparent association with Pleistocene fauna, though it is worth while to note the recognition of a long archeological sequence, which must extend far back of the advent of Eskimo culture on the Bering Sea (Rainey, 1940; Jenness, 1940, pp. 14–15).

On the Asiatic side there are examples of both barbed and toggle harpoons from Japan (Kishinouye, 1909, pp. 336, 341, pl. 22); DeLaguna has drawn attention to the striking similarities in the placement of line holes on toggles from neolithic Japan and Port Möller, Alaska Peninsula (DeLaguna, 1934, p. 189). Soviet work on the lower Amur has yielded archeological results that should be made available in full to American investigators; brief notices and summaries are not enough (Field and Prostov, 1937, pp. 457–490; cf. Zolotarev, 1938).

The Jesup expedition established the hypothesis that there had been an original cultural continuity from the Palae-Asiatic peoples to the Indians of British Columbia, interrupted by the advance of the Eskimo culture in the Bering Strait region. Subsequent work in the north Pacific area has established a continuity, though the relative antiquity of its components has yet to be determined (Birket-Smith, 1930, p. 623; Jenness, 1940, p. 6). Some of the connections seem to have been very early obliterated perhaps by the crystallization of Eskimo culture, while others have surviving links in the Aleutian chain. Collins (1940, p. 583) discusses a number of these and also mentions the very frequent gap in such distributions on the northern Northwest coast; south Alaskan traits which are lacking among the Tlingit and Tsimshian, but which are retained in full vigor on the

southern end of Vancouver Island (Collins, 1940, pp. 576–577). Lantis's (1938, p. 448) whaling cult, to mention only one example, has a gap from Nutka to Kodiak, which can be explained most plausibly by assuming the abandonment of whaling along all but the southernmost Northwest coast. On the west, it is easy to account for the gap in traits between Yezo and the Chukchi Peninsula; the advent of reindeer nomadism in northeast Asia, radically altering the economic pattern of the Tungusic peoples north of the Amur, must have eliminated many fishing and sea-mammal-hunting specializations on the borders of the Sea of Okhotsk. Bogoras (1929, p. 600) has mentioned the difficulties of combining serious fishing with extensive reindeer breeding.

The isolated occurrence of the Ainu double foreshaft toggle harpoon and the wide distribution of the same device in western America may be tentatively interpreted in the following way:

At an early period, perhaps not much later than the time of the first migrations into the New World, use of barbed fish-spears and harpoons was general from northern Asia far into North America. Exploitation of the annual salmon runs around the shores of the North Pacific from the Amur to California, in which barbed harpoon and fish-spears played a part, was probably established relatively early. Sea mammals, especially those frequenting the shoreline, were taken with barbed harpoons. Secondarily the use of single toggle harpoons spread through this area; the present evidence certainly suggests the priority of barbed heads, even though toggles are easier to fabricate.

At a time antedating the crystallization of Eskimo culture on the Bering Sea coasts, the double foreshaft toggle harpoon was invented, possibly on the southern Northwest coast; this invention was spread north and westward, carrying with it details such as the crotched shaft end device, and reinforcing string between divergent foreshafts, either directly across Bering Strait, or, more probably, by way of the Aleutians. Whether it reached Yezo from the Kuriles, or via Sakhalin and the western edge of the Sea of Okhotsk, does not alter the shape of the present conjecture. Gradual abandonment of the double foreshaft toggle device north and west of Yezo may have been due to shift in economic pattern occasioned by reindeer breeding; on the Bering Sea littoral, the abandonment may have been caused by the specialization of sea-mammal-hunting techniques, the growth of dependence on hook and line fishing, and on net fishing. The rôle of fish-trap devices—weirs, pens, fyke baskets, etc.—requires separate study; it can not have been insignificant. On the northern Northwest coast, while no elaboration approaching that of the Eskimo sea-hunting and sea-fishing techniques occurred, the same forces that led to the lapse of whaling, originally continuous from Kodiak to Nutka, may have caused the abandonment of double foreshaft harpoons.

By the time typical Eskimo culture and its influences were settled in the Bering Sea region, and the northern Northwest coast culture had begun to differ from that of the southern coast, the Ainu may have been the only group in northeastern Asia still retaining the double foreshaft toggle harpoon. The Northern Athabaskans who transmitted the trait to the Copper Eskimo must have likewise given it up; the northwestern American distribution had shrunk to the coastal margin of the *Oncorhynchus* area. Scanty evidence in California makes it possible that occurrences of double foreshaft toggle harpoons represent a relatively recent extension southward.

Although there is much archeology yet to be derived from shellmounds in the north Pacific area, the writer feels that they will not yield any extensive series of harpoons with their two toggles still lashed to the spreading foreshafts. The improbability of obtaining such evidence means that the ultimate solution of the present problem must come from other sources.[6] A careful

[6] The Late Predynastic and Early Dynastic Egyptian bident fish-spear, used by nobles for sport-fishing, is known only from paintings. No archeological specimens survive. This device, while it is not a harpoon, has foreshafts of unequal length, giving it a superficial resemblance to the double foreshaft harpoons discussed here (cf. Bates. 1917, pp. 232–245).

laying of the ghosts of the Aleut sea-otter hunters by an exhaustive historical study of their effects on the coastal cultures of the North Pacific from Yezo to Baja California is urgently called for.

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ICHTHYOLOGY.—*The osteology and relationships of the Argentinidae, a family of oceanic fishes.*[1]

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The genus *Argentina* was proposed by Linnaeus and was known before him by Gronow and Artedi. The classification of the argentines has ever since been indescribably mixed up with the Salmonidae, Bathylagidae, Retropinnidae, Osmeridae, Microstomidae, etc. All ichthyologists, up to and including Günther (1866), retained these fishes in the family Salmonidae, and this was continued to as recently as 1929 (Kyle and Ehrenbaum, 1929). Gill (1861) recognized Bonaparte's splitting of the Salmoninae and the Argentininae, but he included part of the osmerid fishes in each of the two subfamilies. This he corrected (Gill, 1862) by including all the smelts with *Argentina* in the Argentininae, placing *Microstoma* in a separate family, and introducing a new subfamily in the Salmonidae for *Retropinna*.

Later, Gill (1884) proposed full family status for the group, although he did not give any diagnosis of the family. As late as 1936 (Fowler, 1936), the smelts and argentines were being grouped together in the Argentinidae.

Regan (1914) first showed the differences between, and clearly defined, the Argentinidae and Osmeridae. His classification has been generally accepted, and further anatomical work (Chapman, 1941) has shown it to be well-founded. Regan, however, considered *Bathylagus* to be an Argentinidae and was followed in this by Norman (1930), Parr (1931), and Beebe (1933), although others, including Barnard (1925), placed *Bathylagus* in the Microstomidae. It has been recently shown (Chapman, 1942) that *Bathylagus* and *Leuroglossus* are only distantly related to *Argentina*, not much more closely related to *Microstoma*, and should be placed in the family Bathylagidae. *Leuroglossus* had been formerly placed in the Argentinidae (Jordan, 1923) and in the Osmeridae (Soldatov and Lindberg, 1930).

As thus restricted, then, the family Argentinidae contains the single genus *Argentina*, of which *Silus* Reinhardt, 1833, *Acantholepis* Kröyer, 1846, and *Glossanodon* Guichenot, 1866, are synonyms. It is the purpose of the present report to describe the osteology of *Argentina* and define the proper position of the Argentinidae in the ichthyological system.

The report is based upon dissections of two specimens of *Argentina sphyraena*, one collected in Christiania Fjord, Norway, by Robert Collett (U.S.N.M. no. 23013), about 192 mm long, and the other taken at Christiania, Norway, by M. G. Hetting (U.S.N.M. no. 17461), about 125 mm long. It is a pleasure to acknowledge the kindness of Dr. Leonard P. Schultz, curator of fishes, U. S. National Museum, in permitting me to work on these specimens.

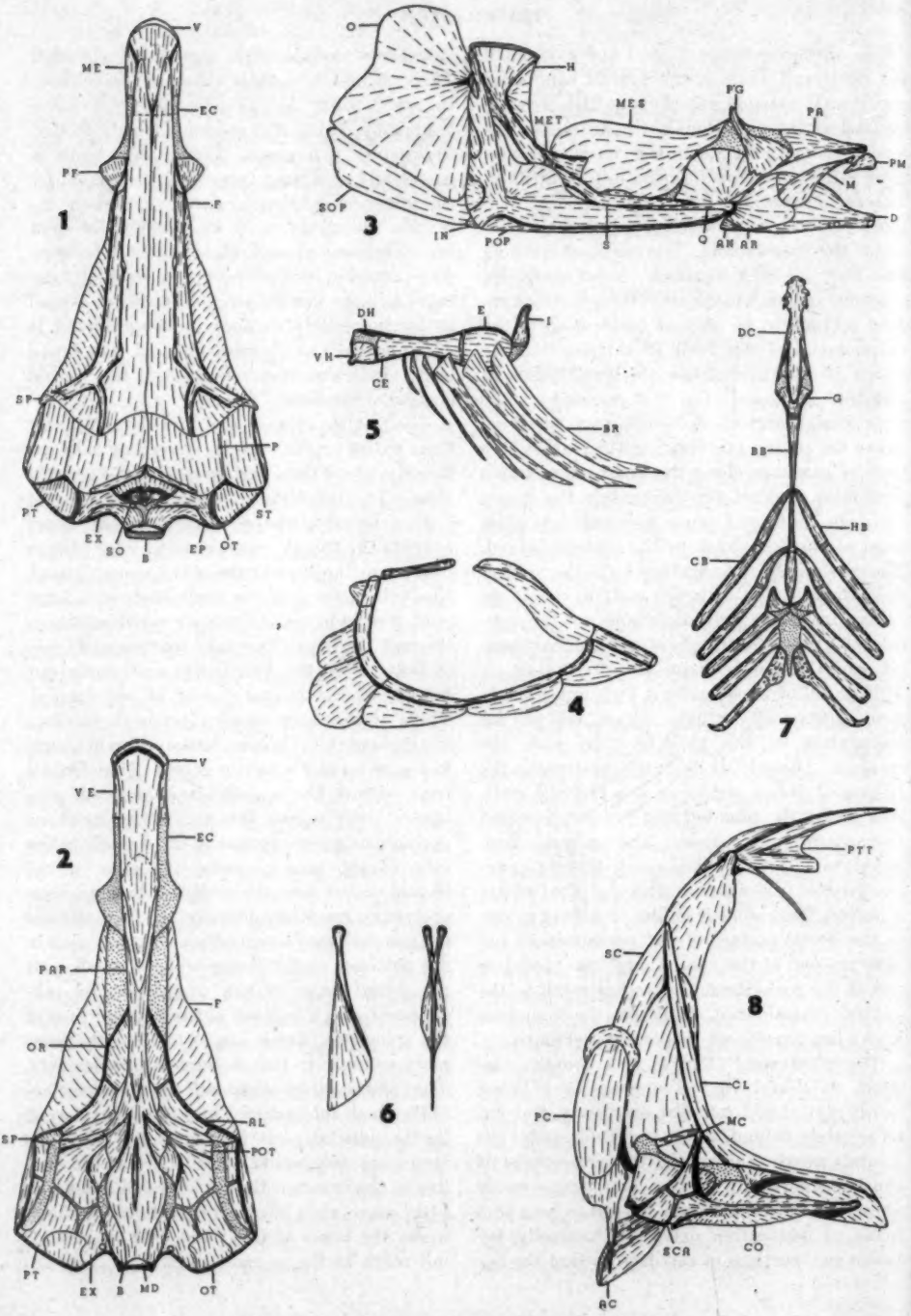
[1] Received September 26, 1941.

THE CRANIUM

The *ethmoid cartilage* (Figs. 1 and 2) is much less developed than in the typical salmonoid cranium. It extends anteriorly a little beyond the end of the mesethmoid to end on the extended vomer. Between the nasal capsules there is a long narrow foramen in the cartilage. The cartilage which forms the dorsal roof of this foramen is an extension of that which lies under the mesethmoid. The cartilage forming the floor of the foramen ends anteriorly squarely against the ventral ethmoid which indeed appears to be only an ossification of the anterior end of this body of cartilage. In the region of the prefrontals the two bodies of cartilage are united but the presence of the large mesial foramen of the olfactory nerve between the prefrontals restricts their union to a strip of cartilage along the inner edge of each prefrontal. Behind the prefrontals the dorsal cartilage splits and sends a broad, but thin, band of cartilage back to the orbitosphenoid. These two bands of cartilage form the ventral protection of the anterior end of the brain cavity from the orbitosphenoid to the prefrontals. The ventral body of cartilage is broadest and thickest between the prefrontals. A little ahead of these bones it puts out a thickened nubbin of cartilage which aids in the articulation of the palatine arch with the cranium. Directly behind the prefrontal the thickened dorsal surface of this body of cartilage is slightly indented and here are inserted the anterior eye muscles. The cartilage then tapers rapidly to a sharp point directly under the base of the anterior spike of the orbitosphenoid. This point is hidden in a deep cavity in the dorsal surface of the parasphenoid behind the end of the vomer. The thin spatulate end of the parasphenoid does not reach to the ventral ethmoid and, therefore, the vomer for a way lies directly on the ventral cartilage.

The *mesethmoid* (Fig. 1) is a complex element. In dorsal view it appears as a broad nearly flat shield rounded anteriorly and cut off squarely behind, where it extends under the frontals nearly halfway to the prefrontals. If the dorsal portion of the bone is cut transversely ahead of the frontals there is seen to be a thin blade of ossification extending ventrally between two portions of cartilage so that the appearance of double origin is given the element. There is also a ventral ethmoid ossification. In such fishes as *Thaleichthys*, *Spirinchus* (Chapman, 1941), and the more closely related *Bathylagus* (Chapman, 1942), this bone is completely separated from the mesethmoid by the intervening ethmoid cartilage. But in *Argentina* the mesethmoid and ventral ethmoid are ankylosed around their anterior borders. The posterior ends of the bones are well separated and the ventral ethmoid does not extend as far posteriorly as does the mesethmoid. It does not reach to the parasphenoid. The broad shaft of the vomer covers most of the ventral surface of the bone.

The *frontals* (Figs. 1 and 2) are separate for their entire length, but are divergent only anteriorly where they part to expose the mesethmoid. The interorbital space is depressed to form a broad V-shaped trough. At the upper edges of the trough, near the outer edge of each bone, runs the closed tube of the sensory canal. The tube ends over the prefrontals in a large pore, from whence the sensory canal continues through the nasal. The tube has branches posteriorly, over the sphenotic, and sends one branch to the lateral corner of the frontal, where the sensory canal extends down onto the circumorbital bones. A second branch ends in a pore on the posterior corner of the frontal from whence the sensory canal proceeds postero-mesially across the parietal to meet its opposite over the supraoccipital. Lateral to the tube of the sensory canal the edge of the frontal arches over the socket of the eye, thus protecting the latter dorsally. On its underside the frontal bears a ventrally projecting wing in the posterior ocular region which extends over the dorsal edge of the orbitosphenoid, alisphenoid, and a portion of the anterior face of the sphenotic, which serves to bind the bone more securely to the chondrocranial elements. The frontals cover about half the dorsal surface of the small sphenotics. They also slightly overlie the parietals, but only enough so that the bones are well bound together. Near the midline of the cranium the parietal and frontal do little more than meet. There is no cartilage under the bones at this point. The frontals do not reach to the supraoccipital.



FIGS. 1-8.—(See opposite page for explanation.)

The *parietals* (Fig. 1) are thin, broad bones of nearly square shape. The bones meet broadly along the midline where the one on the right overlaps the one on the left very slightly. The parietals cover more than two-thirds of the dorsal surface of the small supraoccipital. Together with the supratemporal, whose edge lies over that of the parietal, the parietal of each side forms a complete osseous roof over the anterior two-thirds of the deep temporal fossa, in which are inserted the anterior trunk muscles, thus forming a deep cavern quite unlike the condition in the salmonoid or other opisthoproctoid fishes, and reminiscent of the condition in *Esox*.

Only a small surface of the *supraoccipital* (Fig. 1) is exposed dorsally between and behind the parietals. The bone sends a broad prong anterolaterally along the sturdy cartilage over the anterior semicircular canal. These prongs are covered by the parietals. In contrast to the condition normally found in the salmonids and osmerids, where the dorsal surface is shield-like, nearly circular and extends at least as far as the frontals, the anterior edge of the supraoccipital of *Argentina* is deeply crescentic so that the parietals actually form part of the roof over the brain cavity. The posterior surface of the supraoccipital is at nearly right angles to the dorsal surface. Its broad shield-like area is concave mesially and ends ventrally in a blunt point where it is widely separated from the foramen magnum by the exoccipitals. Near the dorsal angle of the bone a delicate flange projects posteriorly between the muscles of either side. This is connected with the first interneural by a thin ligament.

The *supratemporal* (Fig. 1) is a thin, but broad, bone which, with the parietal, covers the anterior two-thirds of the temporal fossa. Its entire lateral edge is securely ankylosed to that of the underlying pterotic. Anteriorly the bone overlies the dorsal surface of the sphenotic to such an extent that there is only a narrow slit of the latter exposed between the frontal and supratemporal. Anteromesially the bone rests on the cartilage over the anterior semicircular canal, and here in turn it is covered by the frontal. Along its entire mesial edge the bone overlies, and is securely bound to, the parietal. On the dorsal side of the lateral edge of the bone is the slender tube of the sensory canal, which is not completely closed over dorsally. The sensory canal, after leaving the skull at the end of this bone, extends on to pass through a well-formed tube on the lateral face of the supracleithrum which is indistinguishably fused with that bone.

Each *epiotic* (Fig. 1) presents a small dorsal surface, only a small portion of which is covered by the parietal. The rounded angle of the bone which slopes off posterolaterally encloses the posterior semicircular canal of the inner ear. The tiny dorsal surface not covered by the parietal is flattened and the dorsal fork of the posttemporal is attached there by a broad liga-

ABBREVIATIONS USED ON FIGURES

AC	=actinost	E	=epihyal	MD	=myodome	POT	=prootic
AL	=alisphenoid	EC	=ethmoid cartilage	ME	=mesethmoid	PT	=pterotic
AN	=angular	EP	=epiotic	MES	=mesopterygoid	PTT	=posttemporal
AR	=articular	EX	=exoccipital	MET	=metapterygoid	Q	=quadrate
B	=basioccipital	F	=frontal	O	=opercle	S	=symplectic
BB	=basibranchial	FM	=foramen magnum	OR	=orbitosphenoid	SC	=supracleithrum
BR	=branchiostegal ray	G	=glossohyal	OT	=opisthotic	SCA	=scapula
CB	=ceratobranchial	H	=hyomandibular	P	=parietal	SO	=supraoccipital
CE	=ceratohyal	HB	=hypobranchial	PA	=palatine	SOP	=subopercle
CL	=cleithrum	I	=interhyal	PAR	=parasphenoid	SP	=sphenotic
CO	=coracoid	IN	=interopercle	PC	=postcleithrum	ST	=supratemporal
D	=dentary	M	=maxillary	PF	=prefrontal	V	=vomer
DC	=dental cement bone	MC	=mesocoracoid	PG	=pterygoid	VE	=ventral ethmoid
DH	=dorsal hypohyal			PM	=premaxillary	VH	=ventral hypohyal
				POP	=preopercle		

Figs. 1–8.—*Argentina sphyraena* Linnaeus: 1, Dorsal view of cranium of small specimen; 2, ventral view of cranium of small specimen; 3, lateral view of suspensorium of large specimen; 4, circumorbital bones of large specimen; 5, lateral view of hyoid apparatus of large specimen; 6, lateral and dorsal views of urohyal of large specimen; 7, dorsal view of ventral bones of the gill arches of large specimen; 8, mesial view of the shoulder girdle of large specimen. (Figs. 1, 2, and 8, × 3; Figs. 3—7, × 1½, approximately.)

ment. A strongly ossified strut extends laterally under the posterior edge of the parietal and serves to strengthen that thin bone. The anterolateral face of the bone is shallowly concave to form the mesial wall of the temporal fossa. The posterior face of the bone adjacent to the supraoccipital is heavily ossified. Between this flattened surface and the rounded posterolateral corner of the bone, the lower portion of the bone is deeply concave, continuing the adjacent indentation of the exoccipital. The epiotic touches the supraoccipital dorsally, but ventrally the bones are separated by a narrow band of cartilage. A similar band of cartilage separates the epiotic and the exoccipital. The cartilage between the epiotic and pterotic is broader. The opisthotic touches, but does not overlie the epiotic.

The *opisthotic* (Figs. 1 and 2) is a small, thin bone of irregular shape which curves around the cartilage between the epiotic, exoccipital, and pterotic. It is visible from the dorsal aspect, but has no definite dorsal surface. There is an irregular ventral surface of some size lying over the exoccipital, pterotic and the cartilage between the two and extending more than a third of the way to the junction of these two bones with the prootic.

The dorsal surface of the *pterotic* (Figs. 1 and 2) forms most of the floor of the temporal fossa and is mostly excluded from view by the supratemporal. The bone has no definite posterior or lateral surface. It is only a rounded cover over the horizontal semicircular canal and its junction with the posterior semicircular canal. The ventral surface of the bone is marked by the cartilage-lined socket of articulation of the hyomandibular which extends from near the posterodorsal corner of the skull to the junction of the sphenotic and prootic. About half of the hyomandibular articulation is borne on this bone, the rest being on the cartilage between the sphenotic and prootic and, at its anterior end, on the sphenotic. The pterotic is separated from all other cartilage bones of the cranium by a continuous band of cartilage.

The *sphenotic* (Figs. 1 and 2) is a small, but sturdy, bone with three surfaces. The dorsal surface is nearly covered by the frontal and supratemporal. From the corner of the bone a strongly ossified spur which supports the postorbital projects downward. The sphenotic is separated from the pterotic, prootic, and alisphenoid by a continuous, narrow band of cartilage.

The *alisphenoid* (Fig. 2) is a bone of roughly rectangular shape between the orbitosphenoid anteriorly, and the sphenotic and prootic posteriorly. Its dorsal edge is covered by the ventral flange of the frontal. It is separated from the sphenotic by a narrow band of cartilage. The dorsal half of the junction with the prootic is separated by cartilage, but in the lower half the ossifications meet. The anterior ends of the alisphenoids are widely separate.

The *orbitosphenoid* (Fig. 2), which is bilaterally symmetrical, unites the anterior portion of the braincase firmly. On the midline a thin vane of bone projects ventrally. It is extended forward in a fine spike well beyond the main portion of the bone, and a similar, but broader, projection extends posteriorly. From this vane the interorbital septum extends to the parasphenoid. The dorsoposterior corner of the orbitosphenoid is overlapped by the ventral flange of the frontal and thus securely bound to that bone. The entire dorsal edge of the bone abuts on the posterodorsal extension of the ethmoid cartilage. The anteromesial corner is rounded into a cylindrical foramen for the emergence of the large olfactory nerves.

The *prootic* (Fig. 2) is divided into an anterior and lateral face by a sharp ridge that continues the upsweeping line of the parasphenoid wing to the dorsal edge of the prootic at the anterior end of the facet for the hyomandibular. Midway in its length this ridge forms a narrow bridge over the emerging trigeminofacial complex. Two other nerves from this complex emerge in separate foramina on the posterior face of the bone. One extends posteriorly at the dorsal edge of the otolith bulge, the other goes ventrally and emerges on the anterior side of the otolith bulge. On the anterior face of the bone there are also two foramina besides the large opening of the trigeminofacial complex. The dorsalmost one is on the anterior edge of the bone and is not entirely closed, so that it is in fact a deeply rounded notch. The other is more ventral and posterior, directly above the base of the basisphenoid. The two prootics meet ventrally to form the roof of the high, vaulted myodome. The myodome is large anteriorly where its

bottom and sides are formed by the wings of the parasphenoid. It forms a deep channel between the otolith bulges, which is hidden from sight by the flat posterior part of the parasphenoid, and opens posteriorly on the basioccipital under the occipital condyle. The lower portion of the posterior face of the prootic curves outward to form part of the otolith bulges. There is a broad band of cartilage between the prootics and basioccipital, but the bands between them and the other cartilage bones is narrow, although continuous.

The *basisphenoid* is a simple, small rod of bone forking at its dorsal end, sending a short arm to each prootic. It ends ventrally in a small cap of cartilage by which it is attached to the parasphenoid. It serves to separate the posterior eye muscles as they enter the myodome, and to bind the postorbital portion of the cranium more securely to the parasphenoid.

The *basioccipital* (Figs. 1 and 2) forms the entire occipital condyle. Here the bone is constricted and heavily ossified. Anteriorly it broadens out and becomes thinner to form the posterior floor of the otolith bulge. A good deal of its ventral surface is covered by the broad posterior end of the parasphenoid.

The *exoccipital* (Figs. 1 and 2) is the principal bone of the posterior part of the cranium. Prominent on its lateral face is the large foramen of the vagus nerve. Below and ahead of this the bone curves outward to form its share of the otolith bulge. The cartilage at the junction of the exoccipital, pterotic, and prootic is not exposed. The exoccipitals send wings mesially over the posterior surface of the cranium which are separated at the midline by a narrow band of cartilage. These wings form the upper part of the foramen magnum and exclude the supraoccipital from that opening. Lateral to the foramen magnum each bone is deeply concave. The exoccipital rests on the dorsal part of the occipital condyle, but does not enter into its formation.

The spatulate anterior end of the *parasphenoid* (Fig. 2) terminates on the ethmoid cartilage under the nasal capsule, well short of the ventral ethmoid. Its ventral surface is broadly grooved for the reception of the posterior end of the vomer shaft. Its dorsal surface, in the same region, is more deeply grooved yet to receive the posterior end of the ethmoid cartilage. The interorbital portion of the bone is most narrow, but is well ossified and strong. Ahead of the prootics the bone expands and sends broad but short wings to those bones. Behind these wings the bone again expands slightly over the broad cartilage area between the prootics and the basioccipital. It then tapers to a broad end below the occipital condyle.

The *vomer* (Figs. 1 and 2) is a large, long bone. It is widest anteriorly where its single row of small conical teeth, and the continuing rows on the palatine, form the entire dentition of the upper jaw. The bone is also most heavily ossified at this point. It projects anterior to the mesethmoid and is visible from the dorsal aspect. From here the broad, thin shaft tapers gradually backward over the ventral ethmoid, ethmoid cartilage, and parasphenoid to end on the latter, well behind the prefrontals.

SPECIAL OSSIFICATIONS OF THE SENSORY SYSTEM

The *nasal* is a long, slender, tubular bone extending from the anterior edge of the frontal, and ending well forward on the mesethmoid. It lies over the dorsal side of the nasal capsule but extends well to the posterior and anterior sides of that structure. It is incompletely closed dorsally so as to form a trough rather than a tube, although it is roughly circular in cross section. The dorsal opening is expanded at each end and in the middle, where pores open to the dorsal surface of the skull.

There are nine circumorbital bones in the smaller specimen and eight in the larger (Fig. 4), whose thin, yet broad, areas form a protective shield for the lateral surface of the skull. The long and broad preorbital (No. 1) has the appearance of two elements that are nearly indistinguishably anastomosed. The bone's inner (and dorsal) edge lies along the frontal. The element lies over the eye and extends anteriorly to the nasal capsule. The anterior half of the dorsal edge is bent over laterally to form a half-closed tube for the sensory canal. No. 2 is a thin, flat, circular bone lying between the preorbital and the lachrymal, but not entirely filling the space

between them. This bone is absent in the larger specimen. The broad lachrymal (No. 3) extends forward beyond the end of the frontals where it ends in a sharp point. Its posterior dorsal edge is curved over laterally like that of the preorbital to form a trough for the sensory canal. The rest of the circumorbital bones bear a similar trough along their orbital edges, which in no instance is completely closed over to form a tube. Nos. 5 and 6 overlie each other and are ankylosed securely together but their margins are still distinguishable. No. 7 is rather loosely bound to No. 6 by membranes. No. 8 is a tiny bone lying at the corner of the sphenotic which is little more than the trough of the sensory canal. No. 9 is larger and more slender. It is only a curved shell around the sensory canal, like the nasal, and has no broad base. There is a considerable space between No. 9 and the preorbital, which is covered above by the lateral extension of the frontal.

The other special ossifications of the sensory system—tubes on the frontals, supratemporals, supracleithra, preopercles, etc.—are described in their proper places.

UPPER JAW

There are but two elements in the upper jaw (Fig. 3): the *premaxillary* and the *maxillary*. Both are slight, slender, and possess slight function. They are toothless, the entire dorsal dentition being borne by the vomer and palatines. The premaxillary is curved around the snout and attached for its full length to the maxillary. The maxillary is broadened posteriorly where it lies for the most part under the lachrymal. Anteriorly it is slender, but more heavily ossified, and ends in a knob which rests against the cranium.

MANDIBLE

The mandible (Fig. 3) is made up of the *dentary*, *articular*, *angular*, *sesamoid articular*, and *Meckel's cartilage*. The dentary is little larger than the articular. The two bones are overlapped along their junction and firmly ankylosed together. This bond is further strengthened by the heavy Meckel's cartilage, the largest part of which is borne by the articular, but which ends anteriorly in a cavity in the dentary. The lower edge of the dentary is heavy and thickened and, except for the small angular, forms the entire ventral edge of the mandible. The dentary bears no teeth, but the dental surface is sharp and well ossified and could be useful in a shearing action. Along the outer side of the lower edge of the dentary is the tube of the sensory canal. Posteriorly its ventral edge is not completely closed, but anteriorly it is completely closed and tubular and opens to the surface by pores. The sesamoid articular is slenderly ovoid, with its long axis antero-posteriorly. It is thin and rests on top of the columnar Meckel's cartilage. On it is inserted the adductor mandibularis. The articular end of the articular, with its facet, is thick and bulky. The major part of this formation appears to be an ossification of the posterior end of Meckel's cartilage and, therefore, endosteal in origin. The triangular angular is small, but heavy. Its entire posterior end is the surface of insertion of the ligament from the interopercle.

PALATINE ARCH

The elements of the palatine arch (Fig. 3) which are present are the *palatine*, *pterygoid*, *quadrate*, *mesopterygoid*, and *metapterygoid*. The palatine is long and rather slender, but well ossified. It bears a band of tiny conical teeth on its anterior end. They are about thirty in number and arranged irregularly in three rows. The teeth are similar to those of the vomer and are continuous with those. This is made possible by the fact that the dentigerous end of the palatine fits closely in a groove between the ventral ethmoid, ethmoid cartilage, and vomer. For this reason it would be easy in undissected specimens to conclude that all the teeth are on the vomer. The dorsal side of the palatine for its entire length is securely

attached to the ethmoid cartilage. At its posterior end the palatine sends a short, superficial splint of bone along the external side of the pterygoid which serves to bind the two bones more tightly together.

The broad, rather thin pterygoid is irregular in shape. Instead of a clean junction with the quadrate, separated by cartilage, the pterygoid extends a short way along the inner side of the quadrate along the entire edge of junction, and there is, furthermore, a small flange which overlaps the quadrate externally, thus locking the bones securely together. There is a thin, superficial, larger ossification extending from the pterygoid dorsally over the cartilage of the region to lie along the anterior side of the prefrontal, making the junction of the palatine arch to the cranium more secure.

Beside the normal quadrant-shaped main body of the quadrate, and the condyle of articulation for the lower jaw, both of which are heavily ossified, the bone is notable for the length and size of the posterior process which is sent back along the anterior arm of the preopercle. This spike is longer than the main body of the bone. From the lateral aspect it appears razor-thin, but seen dorsally it appears as a broad process tapering to a sharp point under the bend of the symplectic. It lies between the preopercle and the anterior process of the symplectic and binds all these elements together.

The mesopterygoid is much the largest bone in the palatine series. Although broad and long, it is quite thin and pliable. The mesial, or dorsal, end is fairly straight and is bound to the parasphenoid along its entire length. The lower edge is overlain respectively by the metapterygoid, quadrate, pterygoid, palatine, and the cartilage in this region. It forms the roof of the mouth. Although it bears no teeth, there is a rounded patch of heavier ossification in the region of the pterygoid which is perhaps intended for opposition to the large glossohyal teeth below. The bone is shallowly concave on its outer side.

The metapterygoid is a small, thin, triangular bone. The spike-like dorsal end lies against the hyomandibular and the broader ventral end rests on the mesopterygoid. Its strengthening function must be negligible.

HYOID ARCH

The cartilage-capped articular head of the *hyomandibular* (Fig. 3) and the heavily ossified supporting structure form the principal part of the bone. The opercular condyle, which is borne on a short shaft, is likewise heavily ossified. The dorsal angle between it and the articular head of the bone is filled with a wedge of lighter ossification. On the lateral face of the articular head a ridge of bone projects posteriorly and outward. The dorsal part of this ridge slightly overlaps the preopercle and serves to wedge the dorsal end of that bone securely against the opercular condyle. The ventral shaft of the hyomandibular, while not especially broad, or as heavily ossified, as the articular head, is thick and sturdy. A part of its ventral end is covered by the angular flange of the preopercle, and the bones are here again securely bound together by membranes. But between this point and the lateral, more dorsal, ridge of the hyomandibular there is a considerable open space between the two bones. In the anterior angle between the articular head and the ventral shaft is a broad wing of thinner bone.

The *symplectic* (Fig. 3), as usual, is separated from the hyomandibular by a short column of cartilage. It is a long, slender bone, only half the width of the ventral shaft of the hyomandibular. Its long anterior portion is bound to the posterior process of the quadrate and ends in a pad of cartilage in a little concavity on the posterior side of the main body of the quadrate. There is a slight wing of light bone in the broad dorsal angle of the symplectic.

The *interhyal* (Fig. 5) is small but stout. The broad base is capped with cartilage and attached to the epihyal. The more pointed dorsal end is likewise capped with cartilage and inserted in a tiny cup on the inner side of the cartilage between the hyomandibular and symplectic.

The *epihyal*, *ceratohyal*, and two *hypohyals* (Fig. 5) form a long, slender, but heavily ossified, connection between the gill arches and the hyoid arch. The epihyal is only about one-

third the length of the ceratohyal. Around its lower edge and between the two bones is a narrow band of cartilage. The last two branchiostegals are inserted on the side of this cartilage. The two hypohyals are heavy, small bones, the interior of which remains cartilaginous. The dorsal one is securely bound to the junction of the glossohyal and the first basibranchial. On the ventral one is inserted the short, tough ligament of the urohyal.

There are seven *branchiostegal rays* (Fig. 5), all thin and pliable. The first five are attached to the ceratohyal; the last two to the epihyal. The first is tiny, short, and slender. The second is a little broader, but is much longer. The third is somewhat broader and a little longer. The remaining four are broad and have the curved shape of the blade of a saber, each with the proximal end shallowly furcate, and the ventral edge of the blade flattened distally.

The *urohyal* (Fig. 6) is a long, thin, pliable bone, the main part of which is in a vertical plane and lies between the sternohyoideus muscles. The anterior end is slender, strongly ossified and nearly circular in cross section. It splits into two slender rods which reach nearly to the two ventral hypohyals to which they are inserted by very short but stout ligaments. The appearance is that the ligaments have been ossified nearly to the hypohyals.

OPERCULAR APPARATUS

All four opercular elements are present (Fig. 3). The *opercle*, *subopercle*, and *interopercle* are very thin and pliable. Only the facet of the opercle and a short supporting ray behind it are more strongly ossified. The opercle is much the largest of the bones. Its lower edge slightly overlaps the entire dorsal edge of the subopercle and the bones here are tightly bound together by connective tissue. There is only a slight crack of open space between the opercle and preopercle, and the lower part of this is filled by the dorsally projecting process of the subopercle. The interopercle is a long bone nearly entirely hidden from lateral view by the preopercle. It is firmly bound to the subopercle posteriorly, and a short ligament connects it with the angular anteriorly. The *preopercle* is little more than a tube for the sensory canal. The anterior arm is longer than the vertical arm and the two come together at only a little more than a right angle. In the angle is a broad wing of thin bone which overlaps and is bound to the hyomandibular and symplectic. The anterior arm is an open trough. At the angle is a bridge of bone across the trough. The dorsal arm of the bone is made at least semitubular by three other such bridges of thin bone.

GILL ARCHES

The *glossohyal* (Fig. 7) is peculiar because of its dentition and the fact that the dental cement bone is so much larger than the ossification of the glossohyal itself. Only the posterior end of the glossohyal cartilage is ossified where it articulates with the first basibranchial and where the dorsal hypohyals are inserted. The remainder of the glossohyal cartilage extends anteriorly as a long, sturdy rod to the anterior end of the dentigerous surface. The dorsal and lateral surfaces of the cartilage are covered by the thin, dental cement bone. This is purely superficial and can be teased off the cartilage. The two sides do not meet ventrally and the cartilage is there exposed for its full length. This ossification bears nine strong, recurved, conical teeth around its anterior edge, but none at all on its shank in the smaller specimen. The larger specimen has six teeth, as shown in Fig. 7. The teeth are longer than the bone is wide at this point.

The first *basibranchial* (Fig. 7) is very thin, but deep. It is deeply indented on its posterior edge. Here it sends a slender spur posteriorly to the second basibranchial. This bone sends a similar spur from its dorsal edge to the first basibranchial. In between these two spurs is a rectangular open space of some size. The hypobranchials of the first arch are inserted in this open space above the junction of the ventral spur of the first basibranchial with the second basibranchial. The long, slender second basibranchial becomes broader posteriorly but from lateral view it tapers posteriorly until at

its junction with the third basibranchial it is more nearly circular in cross section. The third basibranchial is short and shaped like an awl, with the point posteriorly. The fourth basibranchial is broad, has a flat dorsal surface, and is entirely cartilaginous. From its posterior end a short nubbin of cartilage projects along the floor of the oesophagus between the fifth ceratobranchials.

There are *hypobranchials* (Fig. 7) on the first three arches. Those of the first are narrow, slender rods of bone hardly half the length of the ceratobranchials. Those of the second arch are similar in shape but considerably shorter. The hypobranchials of the third arch are broad and short. They are inserted by their *distal* ends to the anterior edge of the fourth basibranchial and the ceratobranchial. The proximal end is cartilage-capped and projects ventrally as in the osmerid fishes.

There are five pairs of *ceratobranchials* (Fig. 7). They are long, slender bones which become progressively broader, heavier, and shorter, from those on the first arch to the fifth. Those of the third arch are inserted not only on the hypobranchial but on the fourth basibranchial. Those of the fourth and fifth arches are inserted by broad bases on the fourth basibranchial. The ceratobranchials of the fifth arch have expanded proximal ends and on the base so formed on each is a group of several small, blunt, conical teeth.

Epibranchials are present on the first four arches. Furthermore, on the distal end of the fifth ceratobranchial a short rod of cartilage extends inward that may represent the unossified remnant of a fifth epibranchial. The first epibranchial is similar in size and shape to the ceratobranchial. But near its mesial end a short, slender, cartilage-capped projection meets a similar process from the second suprabranchial. There are similar processes for the same purpose on the second and third epibranchials and on the third and fourth suprabranchials so that the gill arches are securely bound together dorsally. The epibranchial of the fourth arch is entirely cartilaginous. It is a simple rod projecting dorsally from the ceratobranchial very much like the condition in *Bathylagus* and *Microstoma* where this cartilaginous fourth epibranchial is attached along the posterior edge of the expanded fourth suprabranchial.

The first *suprabranchial* is a slender, simple rod extending upward from the gill arches to the parasphenoid. It is attached proximally to the first epibranchial and second suprabranchial. Both ends are capped with cartilage. The second suprabranchial is flattened with a pointed, cartilage-tipped anterior end, a pointed cartilage-capped process for articulation with the first epibranchial, and a truncated posterior end which is likewise cartilage-capped and joined to the second epibranchial. The third suprabranchial is quite like the second only a little longer and with a broader posterior end to which are attached not only the third epibranchial but the cartilaginous anterior end of the fourth suprabranchial. The cartilage of the anterior end of the bone is not attached to anything. The fourth suprabranchial is greatly expanded dorsally. A well ossified rod extends from the ceratobranchial mesially, in a position normal for the epibranchial. From the anterior end of this a similar heavily ossified rod extends at a posterior angle dorsally and is of the same length as the first rod. It is capped with cartilage at the end. Between these rods of heavier ossification is a wedge of thinner ossification that makes up most of the surface of the bone. On the posterior surface of this high bone is inserted the broad muscle which extends ventrally to the ceratobranchial below.

On the cartilaginous anterior end of the fourth suprabranchial is borne an oblong, superficial dental cement bone which is covered by a group of about twelve short, conical teeth that oppose those on the fifth ceratobranchial below.

PECTORAL GIRDLE

The dorsal fork of the *posttemporal* (Fig. 8) is larger, broader, and stronger than the ventral fork. It lies just under the skin and is attached by ligament to the epiotic. The main body of the bone bears on its outer side a short, well-ossified tube that carries the lateral line canal, which is open at either end. The ventral fork is slender, nearly circular in cross section and, like the anterior forks of the urohyal, it appears that the ligament has ossified nearly to

the bone of attachment, the opisthotic in this case. It is stiff and stands at nearly right angles to the main body of the bone and the dorsal fork, instead of being in the same plane, as is usual. There is a shallow, broad facet on the inner side of the bone for attachment to the supracleithrum.

The *supracleithrum* (Fig. 8) has a constricted knob at its dorsal end which is attached to the posttemporal. The dorsal third of the bone is thickened by the short tube of the lateral line canal which it bears on its outer surface. The rest of the bone is thin and flat. The bone is slightly concave dorsally to conform to the curvature of the body.

For the most part, the *cleithrum* (Fig. 8) is a thin, flat bone. There is a short dorsal spike from which a ray of heavier ossification extends downward to the insertion of the primary shoulder girdle. Here it is met by a similar strongly ossified ridge from the anterior edge of the ventral arm of the bone. This ridge projects on the inner side of the bone and to this is attached the primary shoulder girdle. A wing of bone projects inward from this ridge to lie over the edge of the coracoid, where there is a slight groove for its reception, and binds the primary shoulder girdle more firmly to the cleithrum.

The primary shoulder girdle (Fig. 8) projects downward at more than a right angle from the cleithrum. The *mesocoracoid*, although slender, and simple, is well ossified and well formed. It ends ventrally in a broadened base on the cartilage between the scapula and coracoid. The edges of those bones are raised to form a simple column for its reception. The bone tapers rapidly to the slender dorsal end where the bone becomes thin and slender and turns posteriorly along the inner surface of the cleithrum to the cartilage over the scapula, thus serving to strengthen the junction between the cleithrum and the primary shoulder girdle.

The *scapula* is large and well ossified. The oval foramen lies nearly in the center of the bone. The lateral edge is straight and attached for its whole length to the cleithrum. The posterior side bears a deeply indented and heavily ossified facet for the articulation of the first ray of the fin. The entire mesial edge participates in the formation of the raised base for the mesocoracoid. It is separate from the coracoid by a narrow band of cartilage. This band expands anteriorly into a broad, thick triangle, the edge of which joins the cleithrum.

The *coracoid* is normal in shape with a short, blunt, posterior process. The anterior process, which attaches to the anterior end of the cleithrum, is long and slender and leaves a broad interosseous space between the coracoid and cleithrum. The posterior edge is thickened and raised to participate in the mesocoracoid base. There are four proportionately large *actinosts*. The first three are inserted on the scapula; the fourth on the scapula and the adjoining cartilage, but not on the coracoid. There is a continuous band of cartilage around the distal ends of the actinosts, over which the fin rays ride, and each of these bones is also capped with cartilage. The first actinost is nearly as broad as long. The remaining bones are also broad, without the typical hour-glass shape, but they become progressively longer until the fourth is three times the length of the first. It is as long as the scapula.

There are four *postcleithra* on the pectoral girdle of the smaller specimen, here described, but only three on that of the larger specimen, illustrated in Fig. 8. The bones are superficial, covered only by thin skin and are visible externally. All are thin. The uppermost is nearly circular and small. It overlaps, and is there bound to the second and also to the cleithrum and supracleithrum. The second is nearly four times the length, and as broad, as the first. The third is only half the length of the second, and is only a little slenderer. The fourth is as long as the second and third, but is less than half as broad. It is attached ventrally to the posterior process of the coracoid and it appears that the whole series is at least a partial support for the primary shoulder girdle. The fourth postcleithrum lies wholly under the pectoral fin. These bones were apparently overlooked by Kendall and Crawford (1922). Unless stained they could easily escape observation by being torn off with the skin.

AXIAL SKELETON

There are 53 vertebra plus the single upturned caudal element, of which 36 are abdominal and seventeen caudal. There are no ribs on the first two. Their places on the centra are taken by ligaments between the cleithrum and supracleithrum and serve to bind the shoulder girdle to the axial skeleton. The ribs on the next 24 vertebrae are adnate to the centra. On the twenty-seventh centrum are short parapophyses to which the ribs are attached. These parapophyses become progressively longer on the remaining nine abdominal vertebrae, and from then on each pair unite ventrally as the haemal spines of the caudal vertebrae. There are no epipleurals on the first nineteen ribs. The next fifteen ribs bear long, slender epipleurals. On the first six of these the epipleurals seem to be ankylosed to the heads of the ribs. The ribs are, in this place, thick and heavy and perhaps represent the fusion of ribs and parapophyses. On the last nine abdominal vertebrae the epipleurals adhere to the parapophyses at the side of the junction with the rib. On the first eight ribs there are slender tendons of the same size and attached in the same position as the epipleurals. It is believed that they are homologous, and also that the ligament on the first vertebra is likewise homologous, with the epipleurals. No sign of epipleural or tendon is seen on the ribs between the ninth and twentieth vertebrae and it is not believed that they were accidentally removed in dissection.

On the first 27 vertebrae are borne long, slender epineurals, quite similar in shape and length to the epipleurals. They are attached at the base of the neural spine and seem to be ankylosed thereto.

The neural spines on the abdominal vertebrae are all slender and pliable. The two spines of each vertebra do not become united into a single spine until the twenty-first vertebra, which is the third behind the dorsal fin. The spines beyond this point become progressively heavier and stiffer.

There are eight thin, but broad, interneurals which fill nearly all the space between the neural spines and the top of the body. The first interneural is enormously expanded, and is much broader than any of the remaining ones.

There are 12 pterygiophores for the dorsal fin. The first is inserted between the neural spines of the ninth and tenth vertebrae, well in advance of the first ray of the fin, and the last, which is tiny, lies between the nineteenth and twentieth vertebrae. The second is the longest and largest, although all of the first three pterygiophores are broad and long.

The rays of the anal fin are borne on thirteen slender pterygiophores between the haemal spines of the first eight caudal vertebrae.

The support of the caudal fin is typically homocercal with a single upturned centrum. The neural spines and haemal spines of the next five anterior vertebrae also lend at least some support to the ray of the fin, the neural spine of the penultimate vertebrae being especially shortened and broadened for this purpose.

RELATIONSHIPS

A review of the anatomy of *Argentina* makes understandable the long association that the argentines have had with the salmonoid fishes in ichthyological systematics. The general shape and proportions of the head and body, the disposition of the fins on the body, the presence of an adipose fin, orbitosphenoid, basisphenoid, the broad and deep myodome, which opens posteriorly, the well-formed and functional mesocoracoid, the several postcleithra, and the peculiarly inverted third hypobranchials (which are so reminiscent of the osmerid fishes) are all typical of the salmonoid fishes. But, on the other hand, the argentines in common with the other opisthoproctoid fishes, and in distinction from the salmonoid fishes, have the following characteristics: (1) Dentition is completely lacking on the premaxillaries and maxillaries, and these bones are much reduced in size and function; (2) there is complete lack of supramaxillaries; (3) the anterior portion of the palatine arch is strongly bound by both cartilage and bony articulation with the ethmoid region of the cranium in the char-

acteristic opisthoproctoid manner; (4) the broad and long mesoptergoid which is obviously destined to aid in the support of the enlarged eye has its ventral edge *under* the cartilage of the palatine arch, not in the same plane with it, and for its entire mesial length it is bound tightly to the parasphenoid; (5) the mesopterygoid and metapterygoid are obviously membrane, not cartilage, bones and the latter is much reduced in size and function; (6) the hyomandibular articulates broadly across the entire lateral edge of the posterior part of the cranium, from the posterior edge of the pterotic to the anterior edge of the sphenotic; (7) the vomer is characteristically broad and thin, has a long posterior shaft (in distinction to the osmerids), and a single row of teeth around the anterior edge which, with the palatine teeth, form the entire dorsal dentition of the mouth; (8) the supraoccipital is broadly shut out from the foramen magnum by the exoccipitals; (9) the fish are exclusively marine and typically bathypelagic with pelagic eggs and larvae (Schmidt, 1918) in abrupt distinction to the normal demersal eggs of salmonoid fishes which are typically buried in, or adhere to, gravel, either near the intertidal area or in fresh water; (10) the cartilage of the cranium, especially of the ethmoid region, is much less developed than in the salmonoids; and last, but by no means least, (11) there is a well-formed and apparently functional spiral valve in the intestine as in the other opisthoproctoid fishes, quite in distinction to the vestigial remnants of spiral valves encountered in occasional specimens of salmonoid fishes (Kendall and Crawford, 1922).

For these reasons the Argentinidae are to be considered as members of the suborder Opisthoproctoidei of the order Isospondyli, although without question they go a long step toward bridging the gap between those bizarre inhabitants of the ocean depths and normal isospondylous fishes. In a group of fishes the members of which are typically widely different from the other members, the Argentinidae diverge especially far, anatomically speaking. To the rest of the Opisthoproctoidei they stand in much the same relation as the Esocidae do to the other families of haplomid fishes: widely divergent, but descended from a similar stock.

The following synopsis of the Argentinidae will serve to distinguish this family sharply from the other opisthoproctoid fishes (Opisthoproctidae, Macropinnidae, Winteriidae, Xenophthalmichthyidae, Bathylagidae, and Microstomidae). Of these fishes it is most closely related to the Microstomidae.

Synopsis of the family Argentinidae.—Opisthoproctoid fishes with several postcleithra, mesocoracoid, basisphenoid, opisthotics, large air bladder, premaxillaries, laterally directed eyes, and a broad myodome that opens posteriorly.

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CHEMISTRY.—*A study of ionic adsorption in solutions of silica and alumina.*[1]

P. G. NUTTING, U. S. Geological Survey.

Some years ago I noted an acid solution of clay that became more acid on the first addition of ammonia. Recently a similar but more pronounced effect was found on adding an alkali to dilute water solutions of pure silica and alumina. This led to finding alkaline solutions that became more alkaline on adding acid. Aside from their purely chemical interest, these findings suggest possible explanations of some puzzling mineral replacements, and the field seemed worth thorough exploration to determine its limits and underlying principles. This task is far from completed but a first summary of results seems in order.

Electrometric titration was the method chiefly used. This gave a series of pH values varying with the amount of reagent added to the solution being studied, which plot in a smooth curve readily repeatable. From among dozens of curves run, I have selected four groups of three concentrations each. These are (1) silica solutions and (2) alumina solutions, each titrated with potassium hydroxide and (3) potassium silicate and (4) potassium aluminate, each titrated with hydrochloric acid.

Impurities were carefully avoided, but it was later found that they had little effect on the shape of a curve, only displacing it slightly. Filter paper, because of its strong adsorption of cations, was not used. Solutions were made up in fresh pyrex glass. Concentrations were determined in platinum. Carbon dioxide from the air interfered with two concentrations of potassium aluminate as noted below. In a freshly diluted or titrated solution a period of 10 to 40 minutes is required to attain an equilibrium pH reading.

Silica solutions are easily obtained by dissolving pure silica in distilled water— about 5 grams in a 4-liter flask. The pure silica is obtained either from silica gel or from a pure bentonite by digesting in hot strong acid for 24 hours to remove bases followed by thorough washing. In hot water, silica approaches saturation (about 0.4 gram per liter) in about 30 hours. The preparation of pure alumina stock solutions by dissolving in hot water was found not to be feasible. Alumina is soluble to the extent of only

[1] Published by permission of the Director, U. S. Geological Survey. Received October 23, 1941.

TABLE 1.—TITRATION OF THREE SILICA SOLUTIONS WITH POTASSIUM HYDROXIDE

10^{-3} gram Si_1O_2/cc 1 mg/100 cc		10^{-4} gram Si_1O_2/cc 10 mg/100 cc		10^{-3} gram Si_1O_2/cc 100 mg/100 cc	
cc or mg KOH	pH	cc or mg KOH	pH	cc or mg KOH	pH
0	5.68	0	5.11	0	4.55
0.5	4.73	1	4.45	2.5	4.15
1.0	4.08	2	3.94	5	3.83
1.5	3.95	3	3.68	7.5	3.61
2.0	10.7	4	3.69	10	3.48
—		5	4.14	15	3.51
—		6	6.30	20	4.25
1.91	7.00	6.25	7.00	23.4	7.00 (neutrality)
1.4	3.94	3.4	3.65	12.5	3.44 (minima)

three parts per million, and the residue containing it was found to be always about 30 percent silica. Bredig's method (arc under water) produced too wide a variety of particle sizes. Finally the ammonia precipitate of the chloride was washed down to about 4 percent chloride, then electrodialyzed. The potassium silica and aluminate solutions were made up by dissolving weighed amounts of silica and alumina in potassium hydroxide of known concentration. For titration, 100-cc portions were used, obtained by successive dilution of the stock with distilled water whose pH varied little from 6.7. The titrating was by half cc steps from a burette containing 0.1 percent (1 mg per cc) acid or alkali. The pH of even 10^{-9} (one part per billion) silica or alumina solution differs markedly from that of the distilled water with which it is diluted. In Table 1 and Fig. 1 are given results for silica solutions of concentrations 10^{-5}, 10^{-4}, and 10^{-3} absolute.

All three solutions became more acid by more than one pH unit on adding the first alkali. At the bottom of Table 1 are given (in pH) the maximum acidity reached, the amount of KOH causing it, and the alkali necessary to neutralize each solution. The stoichiometric ratio is 1.87 grams KOH to combine with each gram of SiO_2 if K_2SiO_3 is formed. That ratio is slightly exceeded in

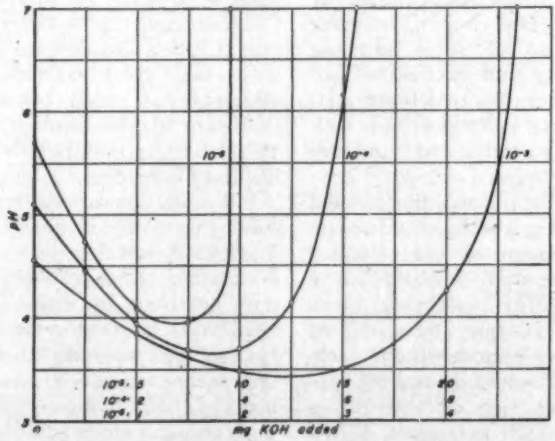

Fig. 1.—Potentiometric titration of 100-cc portions of silica solutions of concentrations 10^{-5}, 10^{-4}, and 10^{-3} gram SiO_2 per cc with 0.1 per cent KOH solution. Note three different abscissae scales for the three curves.

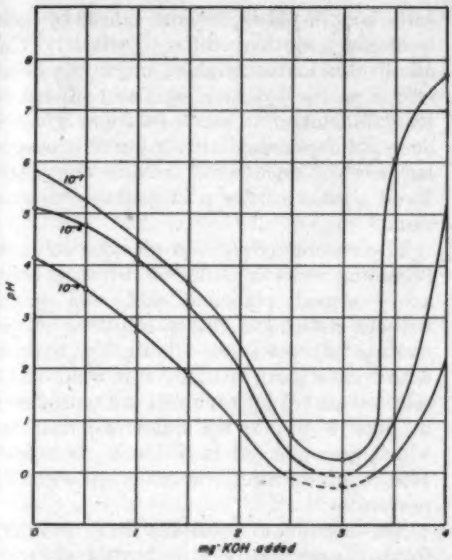

Fig. 2.—Titration of alumina solutions with KOH. Portions of curves below pH = 0 (dashed) are interpolated.

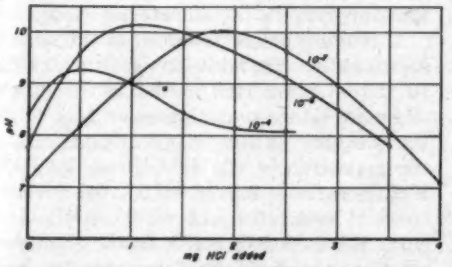

Fig. 3.—Curves showing pH of three dilute solutions of K_2SiO_3 titrated with 0.1 per cent HCl.

TABLE 2.—TITRATION OF ALUMINA SOLUTIONS WITH POTASSIUM HYDROXIDE

cc or mg KOH	10^{-7} 0.01	10^{-6} 0.1	10^{-4} gram/cc 10 mg/100 cc
	pH	pH	pH
0	7.46	5.10	4.15
0.5	5.62	4.75	3.55
1.0	4.51	4.11	2.75
1.5	3.65	3.20	1.86
2.0	2.55	1.95	0.85
2.5	0.72	0.34	(−0.10)
3.0	0.22	(−0.06)	(−0.29)
3.5	6.04	1.00	0.29
4.0	7.68	5.23	2.24

the most dilute solution at pH 7, 0.625 gram KOH per gram SiO_2 being sufficient to neutralize the 10^{-4} solution, and 0.234 the 10^{-3} solution. The more concentrated solu-

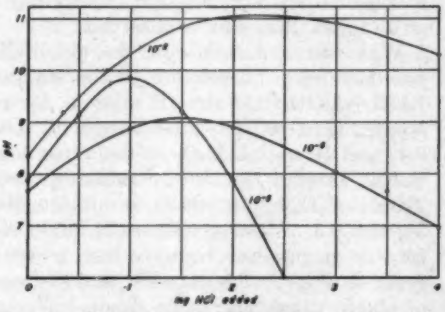

Fig. 4.—Curves showing pH of three dilute solutions of $KAlO_2$ titrated with 0.1 per cent HCl.

tions require proportionately less alkali to neutralize or produce maximum acidity—quite the reverse of alumina solutions. The

TABLE 3.—POTASSIUM SILICATE AND ALUMINATE SOLUTIONS TITRATED WITH HYDROCHLORIC ACID

cc or mg HCl	K_2SiO_3 gram/cc			$KAlO_2$ gram/cc		
	10^{-7}	10^{-6}	10^{-4}	10^{-6}	10^{-5}	10^{-3}
	pH	pH	pH	pH	pH	pH
0	7.12	7.75	8.40	7.68	7.86	8.33
0.5	8.17	9.58	9.25	8.38	9.13	9.50
1.0	9.08	10.12	8.98	8.87	9.84	10.31
1.5	9.80	9.98	8.42	9.08	9.20	10.82
2.0	10.01	9.61	8.12	8.91	7.83	11.04
2.5	9.61	9.10	8.08	8.51	6.01	11.03
3.0	8.98	8.48	8.07	8.02	4.18	10.91
4.0	7.08	—	—	6.95	2.22	10.30
HCl:K_2SiO_3 at max.	185	11	0.05	HCl:$KAlO_2$ at max. 16	1.0	0.0023

amount of alkali required to produce the minimum pH is roughly proportional to the square root of the concentration.

Typical results of titrating pure alumina solutions with KOH are given in Table 2 and Fig. 2 for solutions 10^{-7}, 10^{-6} and 10^{-4} in absolute concentration.

The first addition of alkali to alumina solutions causes a much larger increase in apparent acidity than in silica solutions. pH minima occur with the same addition of KOH at all three concentrations of alumina. With the 10^{-6} and 10^{-4} solutions these minima are below pH = 0. The lowest point reached by the 10^{-4} curve is -0.30 corresponding to an effective hydrogen ion concentration of 2 molar. Such negative (by interpolation) pH values were obtained on a great many titration curves and furnish a clue to the interpretation of the apparently anomalous effects observed.

With alumina solutions, the alkali disposed of bears no relation to the reaction $KOH + AlOOH$. At the pH minima, for example, 3 mg KOH is associated with 0.01, 0.1, and 10 mg of Al_2O_3 in the three solutions. Instead of the combining ratio $2KOH : Al_2O_3 = 1.10$, those ratios are 300, 30, and 0.3. A lowest ratio (0.3) might signify an incomplete reaction but, where a gram of alumina associates with 300 grams of alkali, it can hardly be simple chemical reaction.

Other basic solutions tried with solutions of alumina, silica, and clay include ammonia, alcohol, triethanolamine, sodium hydroxide, and potassium aluminate and fluoride. Many silicates adsorb potassium salts much more powerfully than sodium, salts, but the pH depressions caused by their hydroxides do not differ markedly. The alkali aluminates produce much the same effects as the hydroxides. The addition of triethanolamine to silica solutions gives a deep pH depression but the curve is irregular perhaps due to its tribasic character. Even alcohol causes a measurable depression.

The reverse effect—an alkaline solution becoming more alkaline on titrating with acid—seemed plausible and was found without difficulty. Dilute solutions of potassium silicate and aluminate, titrated with hydrochloric acid show it well. Three selected curves for each salt are reproduced in Figs. 3 and 4, the numerical data for which are collected in Table 3. As before, 100 cc of solution was titrated with 0.1 percent acid.

The aluminate solutions 10^{-4} and 10^{-3} formed precipitates (by hydrolysis?) on standing. Their residual liquors gave pH curves similar to that for 10^{-6} which is the solubility of the hydroxide. No such effect was apparent in the silicate solutions.

Maximum pH is produced in the silicate solutions by the addition of from 0.5 (in 10^{-4}) to 1.8 mg HCl in the 10^{-7} solution, the more dilute requiring more acid, quite the contrary of any chemical reaction. At the maximum of the 10^{-4} curve the HCl: K_2SiO_3 ratio is $0.5 : 10 = 0.05$, on the 10^{-6} curve it is $1.1 : 0.1 = 11$ while on the 10^{-7} curve it is $1.85 : 0.01 = 185$. In the aluminate solutions the disparity is even greater. Evidently both adsorption and hydrolysis play important roles.

DISCUSSION

Only tentative suggestions bearing on the results recorded above appear possible at this time. Although they appear to be caused by selective adsorption, the details are far from clear.

The study of electrolytic conduction 40 years ago showed that each migrating ion carried from 10 to 30 molecules of water with it. The miscellae of silica and alumina sols are notoriously avid adsorbers of ions and on electrodialysis are dragged through the membranes by both anions and cations. In pure water, with H and OH ions present in equal numbers and strength, the migration of silica or gelatin is impartially toward anode and cathode. The addition of a little KOH or HCl to the sol throws the migration far off balance.

An alkaline precipitate in an acid solution may be readily obtained. To a suspension

of sodium clay (e.g., a swelling bentonite) methyl orange is added, then just sufficient acid to cause precipitation. If carefully done the precipitate will be yellow and the solution red. An acid precipitate in an alkaline solution may be obtained from the same clay by first treating with acid to remove alkali, then neutralizing with alkali. These tests show the powerful selective adsorption of alumino-silicates. Silica gel turns pink when wet with water containing methyl orange, the liquor turning yellow.

The large changes in pH noted in some cases would seem to indicate that heavy concentrations of H (or OH) ions might occur in a thin layer on the glass electrode or at the boundary of the KCl solution. Wiping the glass electrode or rinsing it with distilled water, with or without previous soaking in salt solution, did not affect the pH reading. Replacing the solution being observed with fresh solution was also without effect. A polarization effect is improbable because of the infinitesimal current used for only a small fraction of a second in making a reading and because standing over night did not affect the reading.

Mattson[2] has recently suggested that soil humus, under certain conditions of oxidation, might be made more acid on the addition of an alkali by permitting the escape of free hydrogen during the oxidation-reduction process. If Mattson's theoretical prediction is realized in actual tests, it may point to an explanation of the simpler and much more general results here reported, but its present application to these results is not apparent.

The wide diversity of cases in which inverse pH effects were noted suggested that perhaps many classes of chemical reaction start off with the adsorption of ions and continue so until the adsorption of ions is sufficient to pass the potential hump and complete the reaction. Not denying this possibility, one notes that in some cases reported the reverse effect is at its height with reagent more than a hundred times that called for by the chemical reaction. This would seem to mean an enormous increase in the chemical energy hump with extreme dilution.

The dissociation of water supplies ions of about the same concentration (10^{-7} moles) as that of some of the solutions worked with but it is difficult to see how these ions could be effective in producing an unbalance between anions and cations.

The break-up of long chains of solute into shorter ones and eventually into single molecules would produce an unbalanced demand for OH ions to fill out broken ends leaving excess H ions and acidity. Conversely, the building up of such chains would produce excess OH ions. For a time this explanation seemed acceptable to the writer but it was later found to be inadequate for it would require that a reagent break up (or build up) chains, at a fixed concentration, according to a very definite law. This seems very improbable particularly at the lowest concentrations where the solute probably exists as single molecules.

The ultimate explanation of the observed effects seems likely to be based on selective adsorption; that is, on the formation of ion-rich osmotic atmospheres surrounding miscellae and molecules of silica and alumina.

SUMMARY

Experiments are described in which the addition of alkali to acid solutions renders them more acid and in which the addition of acid to alkaline solutions increases their alkalinity.

Curves of electrometric titration of silica and alumina solutions with potassium hydroxide are smooth and show a regular progression with concentration. The silica curves drop about 1.5 pH units, the alumina curves about 5 units before the final rise to alkalinity. The silica solutions reach maximum acidity on addition of alkali just less than the combining proportion, the alumina solutions on addition of a fixed amount of alkali which, in the most dilute solution, is 300 times the combining proportion.

In titrating solutions of potassium silicate

[2] MATTSON, SAUTE. *The acid-base condition in vegetation*: Ann. Agr. Coll. Sweden 9: 50. 1941.

and aluminate with hydrochloric acid the pH first rises by from one to three pH units before the final decrease to neutrality. At the maxima of these curves, the ratios of acid to alkali vary enormously with concentration and in inverse proportion.

The explanation of the observed anomalous behavior of these titrations is held to lie in a high selective adsorption.

PROCEEDINGS OF THE ACADEMY

373D MEETING OF BOARD OF MANAGERS

The 373d meeting of the Board of Managers was held in the Library of the Cosmos Club on February 6, 1942. President CURTIS called the meeting to order at 8:08 P.M., with 17 persons present, as follows: H. L. CURTIS, F. D. ROSSINI, H. S. RAPPLEYE, N. R. SMITH, W. W. DIEHL, R. J. SEEGER, F. H. H. ROBERTS, JR., F. G. BRICKWEDDE, H. B. COLLINS, JR., F. C. KRACEK, J. B. REESIDE, JR., J. E. MCMURTREY, JR., W. A. DAYTON, F. B. SILSBEE, E. W. PRICE, L. W. PARR, and C. L. GARNER.

The minutes of the 372d meeting were read and approved.

President CURTIS announced the following appointments, for 1942 unless otherwise stated:

Executive Committee: J. E. GRAF, L. W. PARR.

Board of Editors of the JOURNAL: R. J. SEEGER, Senior Editor; J. R. SWALLEN, to January, 1945.

Associate Editors of the JOURNAL: W. E. DEMING, representing the Philosophical Society, to January, 1945; C. F. W. MUESEBECK, representing the Entomological Society, to January, 1945.

Committee on Membership: F. C. KRACEK (chairman), F. P. CULLINAN, F. M. DEFANDORF, ALICE C. EVANS, C. L. GAZIN, and J. S. WADE.

Committee on Monographs: ALEXANDER WETMORE and J. H. KEMPTON, to January, 1945.

Committees on Awards for Scientific Achievement: ALEXANDER WETMORE, general chairman.

For the Biological Sciences: ALEXANDER WETMORE (chairman), J. H. KEMPTON, F. H. H. ROBERTS, JR., W. A. DAYTON, C. F. W. MUESBECK, L. W. STEPHENSON and E. W. PRICE.

For the Engineering Sciences: H. N. EATON (chairman), G. W. VINAL, W. D. SUTCLIFFE, W. J. ROONEY, H. C. HAYES, O. E. MEINZER, and C. S. PIGGOT.

For the Physical Sciences: L. V. JUDSON (chairman), A. T. MCPHERSON, K. F. HERZFELD, O. S. ADAMS, F. S. BRACKETT, L. H. ADAMS, and R. C. WELLS.

Committee of Tellers: W. RAMBERG (chairman), L. W. BUTZ, and P. S. ROLLER.

Committee of Auditors: J. W. ROBERTS (chairman), E. W. POSNJAK, and C. H. SWICK.

Committee on Meetings, from June, 1942, to May, 1943: J. H. KEMPTON (chairman), K. S. GIBSON, M. C. MERRILL, ATHERTON SEIDELL, and P. A. SMITH.

The Executive Committee reported that it had instructed the Treasurer to invest the $4,000 mentioned in the previous report as available for reinvestment in U. S. Savings Bonds of Series G at 2½ per cent interest, instead of in a savings account in a new federally-insured savings and loan association. The Executive Committee also presented the following budget for 1942, which was approved by the Board:

BUDGET

	Allotments	
	1941	*1942*
Secretary	$ 450	$ 450
Treasurer	225	200
Archivist	—	10
Custodian and Subscription Manager of Publications	120	75
Committee on Meetings	350	300
Committee on Membership	10	10

Executive Committee		10		10
Board of Editors		3,400*		3,100*
Printing, mailing, engraving, reprints	3,100		2,800	
Editorial assistance	240		240	
Miscellaneous expenses	60		60	
Directory		350		—
Addendum to the Directory		—		60
Total		4,915		4,215

ESTIMATED INCOME FOR 1942

Dues	2,575
Subscriptions and sales of the JOURNAL	615
Interest and dividends	1,049
Total	4,239

* Not including services charged to, and paid for by, authors or their sponsors.

The two nonresident persons whose nominations were presented to the Board on January 9, 1942, were considered individually and duly elected to membership.

The Committee to consider certain questions relating to the Committee on Membership (F. C. KRACEK, chairman) reported some suggestions, which were referred for the making of definite recommendations to a second committee.

The Committee to consider affiliation of the Academy with the American Association for the Advancement of Science (N. R. SMITH, chairman) recommended such affiliation, which was thereby authorized to the Board.

The Secretary reported the following changes in membership: Acceptances, 1; qualified, 2; resignations, 3; retirements, 1. The status of membership as of February 6 was as follows:

	Regular	*Retired*	*Honorary*	*Patrons*	*Total*
Resident	434	34	3	0	471
Nonresident	127	19	13	2	161
Total	561	53	16	2	632

The Treasurer, H. S. RAPPLEYE, reported that, in accordance with the instructions of the Executive Committee, he had invested $4,000 in U. S. Savings Bonds of Series G at 2½ per cent interest.

The Board approved the recommendation of the Custodian and Subscription Manager of Publications, W. W. DIEHL, that 900 copies of the JOURNAL (the same as in 1941) be printed for 1942 and until further notice.

Upon nomination by the Anthropological Society of Washington, F. M. SETZLER was elected a Vice-President of the Academy for 1942 representing that Society.

The Board authorized the President to appoint a Committee to consider the petition for affiliation with the Academy that the Secretary reported received from the District of Columbia Society of Medical Technologists.

The Board instructed the Archivist to deliver to the Board at its next meeting a report on, and the contents of, the sealed package in the Archives relating to the ballots, etc., pertaining to the selection of the original membership of the Academy by the Joint Commission of the Scientific Societies of Washington.

The Board authorized the President to appoint a Committee to consider ways and means of increasing the income of the Academy.

The meeting adjourned at 10:18 P.M.

310TH MEETING OF THE ACADEMY

The 310th meeting of the Academy was held in the Assembly Hall of the Cosmos Club at 8:15 P.M. on February 19, 1942, with President CURTIS presiding.

GEORGE C. VAILLANT, director of the Museum of the University of Pennsylvania, Philadelphia, Pa., delivered an address entitled *The Aztecs of Mexico*, in which it was shown that archeology has a more direct bearing on history in Mexico than in the United States because the Indian population there is almost as important now as in the past. Excavations and docu-

mentary manuscripts were discussed, and the evolution of civilization in Indian Mexico was described.

There were about 90 persons present. The meeting adjourned at 10 P.M. for a social hour.

FREDERICK D. ROSSINI, *Secretary*

Obituary

ERNEST EVERETT JUST died on October 27, 1941. Born August 14, 1883, at Charleston, S. C., he received his early education at Kimball Union Academy in New Hampshire and his A.B. degree at Dartmouth College in 1907. At Dartmouth he specialized in zoology, devoting much of his time to research, and was elected to Phi Beta Kappa. His graduate training was begun at Woods Hole, Mass., under Prof. Frank R. Lillie while he was a member of the faculty of Howard University, and he received his Ph.D. from the University of Chicago in 1916. He was a member of the staff of Howard University from 1907 until his death, being head of the department of zoology from 1912. Most of his summers from 1909 to 1930 were spent at the Maine Biological Laboratory at Woods Hole. During the last 10 or 12 years he conducted his researches in various European laboratories. Just published over 50 papers dealing with fertilization and experimental parthenogenesis in marine eggs, chiefly of annelids and echinoderms. He also published two books, *Basic methods for experiments in eggs of marine animals* and *The biology of the cell surface*. Much of his research was made possible by grants from Julius Rosenwald, the General Education Board, the Carnegie Corporation, and the Rosenwald Foundation with which Howard University cooperated wholeheartedly by extending him numerous prolonged leaves of absence.

He was a member of many societies, among them the American Association for the Advancement of Science, the American Society of Naturalists, the American Society of Zoologists, the Ecological Society of America, and the Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg.